these same requirements. Care must be exercised in the control of the flow of this condenser water, as the temperature can vary between 95+ and 35 degrees Fahrenheit (35+ and 1.7 degrees Celsius). Low condenser water temperature can cause an internal pressure reversal in the water chillers that can render them inoperable. Consultation with the water chiller manufacturer is essential to ensure that proper flow and pressure controls are provided to prevent this from occurring. In addition, condensers must be sized to ensure they can produce the required emergency cooling load when the plant's emergency raw water cooling system is switched to the ultimate heat sink (such as a standby nuclear service water pond).

The refrigerant portion of the water chillers' heat exchangers is constructed to the requirements of ASME Section VIII[62] and ASME AG-1, Section RA.[30] The refrigerant system, including the compressor, valves, interconnecting piping, etc., is constructed to the requirements of ASME AG-1, Section RA.[30]

The chilled water portion of the water chillers' heat exchangers (system piping, valves, pumps and cooling coils for the air handling units) are constructed to the requirements of ASME Section III, Class 3,[50] and ASME AG-1, Sections RA and CA[30] Section CA of ASME AG-1 also contains requirements for other types of conditioning equipment.

2.5 AIR CLEANING SYSTEMS FOR FUEL PROCESSING AND REPROCESSING PLANTS

Air cleaning systems for fuel processing plants rely on multistage HEPA filtration. The airborne radionuclides of primary concern are radioactive particles and aerosols, tritium, carbon-14, krypton-85 and iodine-129. Due to heavy particulate loads and radiation levels, most systems are bag-in/bag-out housings that provide protection during filter change-out. Bag-in/bag-out housings are discussed in Chapter 4. Typical air cleaning systems are shown for horizontal flow (**FIGURE 2.5)** and vertical flow (**FIGURE 2.6)**. Housings must be installed with the filter clamping mechanisms downstream to keep them clean and free of contaminants.

Additional guidance for air cleaning systems for fuel processing and reprocessing can be found in the following references:

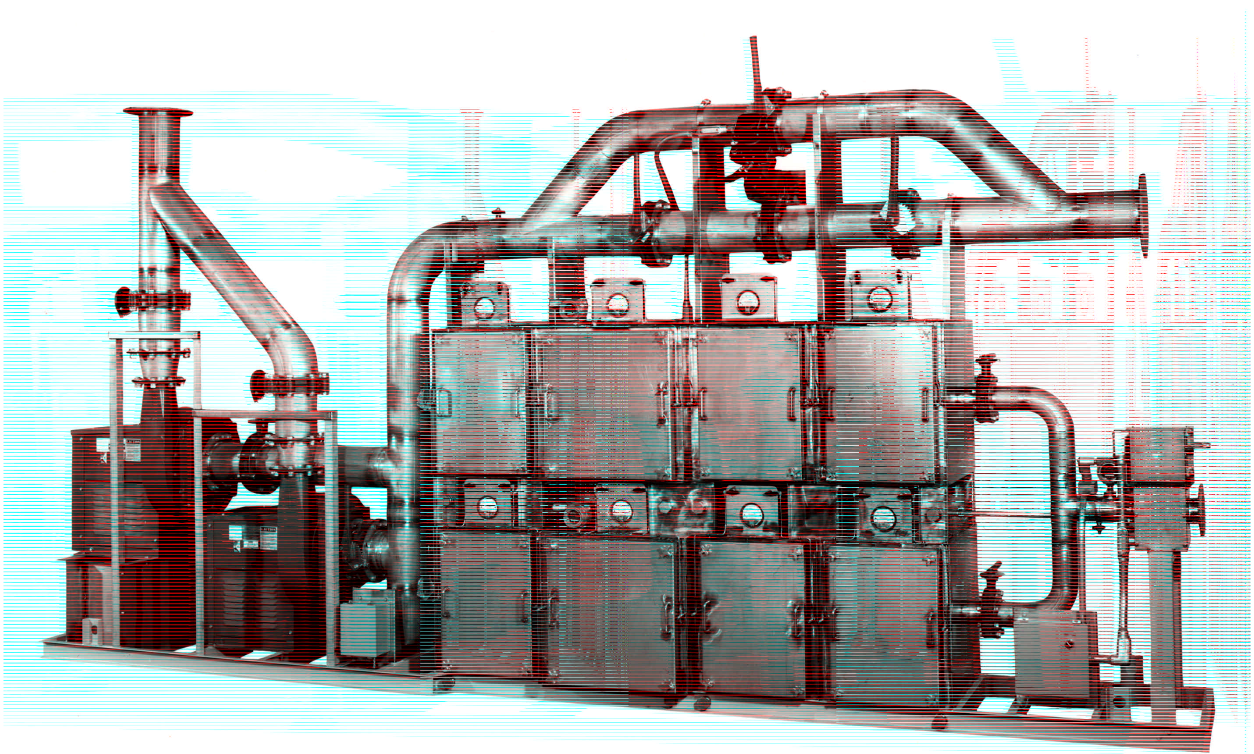

Figure 2.5 – Typical air cleaning system (horizontal flow)

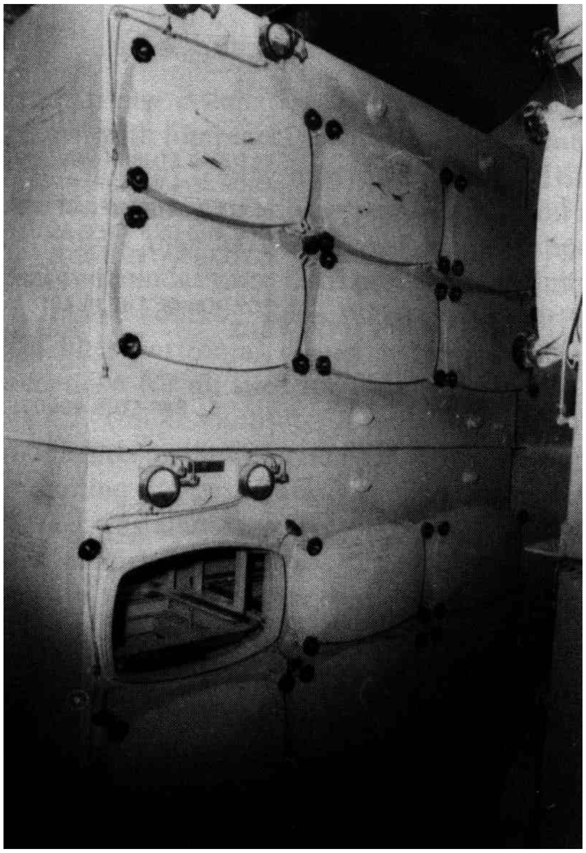

Figure 2.6 – Typical air cleaning system (vertical flow)

- Regulatory Guide 3.12, "General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants." [5]
- Regulatory Guide 3.18, "Confinement Barriers for Systems for Fuel Processing Plants." [18]
- Regulatory Guide 3.30, "Process off-Gas Systems for Fuel Processing Plants."[52]
- Regulatory Guide 3.32, "General Design Guide for Ventilation Systems for Fuel Processing Plants."[53]

2.5.1 AIR CONDITIONING, HEATING, AND VENTILATING SYSTEMS FOR THE BALANCE-OF-PLANT

Air conditioning systems for the balance-of-plant (warehouses, turbine/generator halls, shop areas, office areas, laboratory areas, etc.) are generally designed in accordance with the practices outlined in the ASHRAE Application Handbook,[30] and other sources such as the Industrial Ventilation Manual.[34] These systems usually must also meet state and local building codes as well as federal regulations (e.g., Occupational Safety and Health Administration regulations).

The following balance-of-plant areas are of particular importance.

Turbine/Generator Halls. These areas of the plant are usually large, enclosed spaces that house the Turbine/Generators and the feedwater heaters, reheaters, piping, and other miscellaneous balance-of-plant equipment. The design temperature is typically 120 degrees Fahrenheit (49 degrees Celsius) for summer conditions and approximately 60 degrees Fahrenheit (16 degrees Celsius) for winter conditions. These areas are typically provided with multiple roof exhaust fans with louvers/dampers set in the outside walls at the lowest level possible. This allows outside air to be drawn into the building, to rise through various openings in the floors, and eventually to be exhausted by the roof fans. Experience has shown that these areas have higher heat loads than anticipated and that extra fans or spray humidifiers have to be added to make the building comfortable enough for routine maintenance and inspection, particularly the operating deck. Unit heaters provide heating. These are supplied with steam or hot water from the plant heating system. Heaters are strategically placed to prevent freezing of piping and equipment. Outside air louvers must have shut-off dampers so they can be closed during times when the outside air is below freezing.

Shop, Decontamination, and Laboratory Areas. Shop areas, decontamination areas, or laboratories handling radioactive materials or dangerous chemicals require special attention to be given to any exhaust systems required. Fume hoods and gloveboxes are covered in Section 2.2.9. In addition, if explosive or corrosive chemicals/materials are being used in these areas, the components of the exhaust system must be able to withstand the effects of the chemicals. Wherever explosive chemicals/materials are being used, all motors and controls for the exhaust system must be explosion-proof.

2.5.2 SYSTEM NOMENCLATURE

Single-component air cleaning units. A single-component air cleaning unit is one in which there is only one component (HEPA filter, prefilter, etc.) per stage, as opposed to a bank installation in which there are two or more components per stage.

Single-path systems. A single-path system is one in which the total installed capacity of the air cleaning system is installed in a single air cleaning unit.

Segmented systems. A segmented system is a parallel configuration in which the installed capacity necessary to meet system design airflow requirements has been subdivided into two or more parallel air cleaning units.

Branched systems. A branched system is a parallel configuration with a common entrance duct or inlet, a common discharge duct, or both.

Isolatable units/components. An isolatable unit is an air cleaning unit that can be isolated from other units that comprise the system via dampers, backflow preventers (dampers), fan location, or system layout, and also can be operated simultaneously with, or alternatively to, the other units that comprise the system.

Compartment units. A compartmented unit is an air cleaning unit in which stages of components are installed in individual compartments in series.

2.5.3 MULTISTAGE FILTRATION

Series Redundancy. In highly contaminated areas and/or applications such as fuel processing and reprocessing plants, redundant systems are recommended for primary and secondary confinement. Their purpose is to increase the reliability of the system by providing backup filtration in the event of damage, deterioration, or a failure in the first-stage filters. Each stage of filtration (each filter bank) must be individually testable to claim credit for redundancy.

Increased Decontamination Factor. A HEPA filter by definition, has a minimum efficiency of 99.97 [Decontamination factor (DF) = 3333] for 0.3-μm particles. DFs of at least 10^{11} are recommended for plutonium in gaseous effluents. Although some decontamination is effected by plant operations, the greatest portion must come from the HEPA filters, which means that two, three, or even more stages of HEPA filters may be necessary.

In theory, the DF of a multistage HEPA filter installation will be $DF_f{}^n$ where DF_f is the DF of a single HEPA filter stage (3333) and *n* is the number of stages. Consideration should be given to assigning a reduced decontamination factor for the secondary stages. Actual DFs may be reduced in secondary stages possibly due to the lower upstream concentration of contaminants, upset conditions, or deterioration and aging of the HEPA filters. For purposes of assigning safety credit in facility safety reports, a conservative decontamination factor should be used.

2.6 OPERATIONAL CONSIDERATIONS

2.6.1 MODE OF OPERATION

According to operational requirements, an air cleaning system may be operated full-time or part-time, or simply be held in standby for emergency service. If processes in a building are operated only one or two shifts a day, the designer may have a choice between continuous operation and operation only during those shifts. The designer must evaluate the effects of daily starts and stops on the performance and lifetimes of filters and other components versus the higher power and maintenance costs that may be incurred by continuous operation. Experience has shown that, all factors considered, continuous operation of air cleaning facilities, perhaps at reduced flow during weekends and holidays, is generally the most satisfactory mode of operation for buildings in which radioactive operations are conducted. Unless ducts, filter housings, damper frames, and fan housings (i.e., the pressure boundary) are extremely leaktight, out-leakage of contaminated dust into occupied spaces of the building may occur during shutdown periods.

Many facilities require standby exhaust or air cleanup systems that are operated only in the event of an emergency or for periodic testing. When designing standby systems, the engineer must keep in mind the possibility of corrosion and filter and adsorber deterioration even when the system is not in use.

In commercial nuclear power plants, air cleaning systems are either continuously operated (since